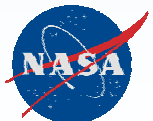


High Energy Power and Propulsion (HEP & P)  
Capability Roadmap  
Status Report  
Nov. 29, 2004

Joseph J. Nainiger, Chair  
NASA Glenn Research Center  
Thomas Hughes, Co-chair  
Penn. State Univ., Applied Research Lab



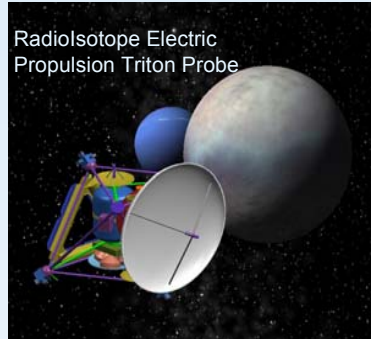
# HEP & P Summary

- Capabilities conveyed within HEP & P shall be developed in context of three broad application areas for future Exploration and Science missions
  - Provide Planetary Surface Power
    - Photovoltaic power systems with energy storage for stationary and mobile applications
    - Nuclear fission power systems for stationary applications
    - Radioisotope power systems for stationary and mobile applications
  - Provide In-Flight/On-Orbit Power
    - Photovoltaic power systems
    - Nuclear fission power systems
    - Radioisotope power systems
  - High Energy Propulsion Systems
    - High power solar electric
    - Nuclear fission electric
    - Radioisotope electric
    - Nuclear thermal

# HEP & P Relevance



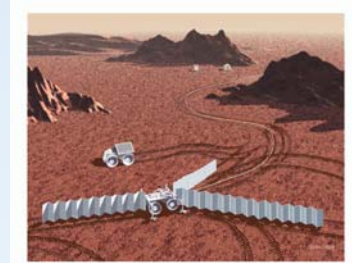
SEP/Chemical Mars Transport Stage



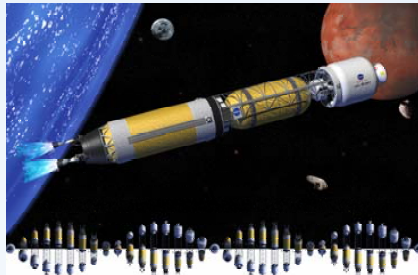
Radioisotope Electric Propulsion Triton Probe



15 MWe NEP Mars Piloted Vehicle



Nuclear Fission Mars Power System  
Radioisotope Powered Cart



Nuclear Bi-Modal Piloted  
Nuclear Thermal Rocket



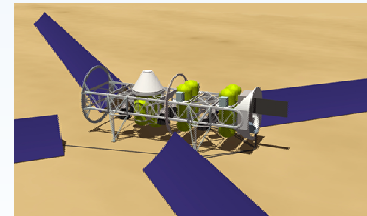
Nuclear Fission Lunar Power System



Photovoltaic Powered Robotic  
Lunar Lander



Radioisotope Powered  
Deep Space Probe



Photovoltaic Mars Power System



Photovoltaic Powered Mars Rover

# Photovoltaic Power Systems Breakdown Structure

- Photovoltaic arrays
  - Solar cells
  - Concentrator concepts
  - Array blankets
  - Array structures
- Energy Storage
  - Batteries
  - Regenerative fuel cells
    - Electrolyzers
    - Fuel Cells
    - H<sub>2</sub> – O<sub>2</sub> tanks
  - Flywheel
- Power Management and Distribution
  - DC-DC converters
  - Cabling
  - Charge/Discharge control
  - Shunt regulator

# Nuclear Fission Power Systems Breakdown Structure

- Nuclear Fission Reactor
  - Fuels and cladding
  - Controls
  - Shielding
- Power Conversion Devices (various types – Brayton, Stirling, thermoelectrics, etc.)
- Heat Rejection Systems
  - Materials
  - Structure
- Power Management and Distribution
  - AC-DC converters
  - DC-DC converters
  - Cabling

# Radioisotope Power Systems Breakdown Structure

- GPHS Modules
- Power Conversion Devices (various types – Brayton, Stirling, thermoelectrics, etc.)
- Heat Rejection System/Housing
- Power Management and Distribution
  - AC-DC converters
  - DC-DC converters
  - Cabling

# Solar Electric Propulsion Systems Breakdown Structure

- Photovoltaic arrays
  - Solar cells
  - Concentrator concepts
  - Array blankets
  - Array structures
- Power Management and Distribution
  - DC-DC converters
  - Cabling
  - Charge/Discharge control
  - Shunt regulator
- Electric Propulsion Subsystem
  - Thrusters
  - Power Processing Units
  - Tankage and propellant feed system
- Guidance and Navigation (In Conjunction with In-Space Transportation Team)
- Avionics (From In-Space Transportation Team)
- Vehicle Health Management (From In-Space Transportation Team)

# Nuclear Electric Propulsion Systems Breakdown Structure

- Nuclear Fission Reactor
  - Fuels and cladding
  - Controls
  - Shielding
- Power Conversion Devices (various types – Brayton, Stirling, thermoelectrics, etc.)
- Heat Rejection Systems
  - Materials
  - Structure
- Power Management and Distribution
  - AC-DC converters
  - DC-DC converters
  - Cabling
- Electric Propulsion Subsystem
  - Thrusters
  - Power Processing Units
  - Tankage and propellant feed system
- Guidance and Navigation (In Conjunction with In-Space Transportation Team)
- Avionics ( Address unique nuclear requirements)
- Vehicle Health Management (Address unique nuclear requirements)



# Radioisotope Electric Propulsion Systems Breakdown Structure

- GPHS Modules
- Power Conversion Devices (various types – Brayton, Stirling, thermoelectrics, etc.)
- Heat Rejection System/Housing
- Power Management and Distribution
  - AC-DC converters
  - DC-DC converters
  - Cabling
- Electric Propulsion Subsystem
  - Thrusters
  - Power Processing Units
  - Tankage and propellant feed system
- Guidance and Navigation (In conjunction with In-Space Transportation Team)
- Avionics ( Address unique nuclear requirements)
- Vehicle Health Management (Address unique nuclear requirements)

# Nuclear Thermal Propulsion Systems Breakdown Structure

- Nuclear Fission Reactors
  - Fuels and cladding
  - Controls
  - Shielding
- Power Conversion (For Bi-Modal options)
- Fuel Tanks (Address materials considerations unique to nuclear radiation environment)
- Pumps (Address technology issues related to long run times and nuclear radiation environment)
- Nozzles (Address technology issues related to long run times and nuclear radiation environment)
- Guidance and Navigation (From In-Space Transportation team)
- Avionics (Address unique nuclear requirements)
- Vehicle Health Management (Address unique nuclear requirements)

# HEP & P Process

- 1) Divide capabilities roadmap team into the following 6 subteams (tentative)
  - Photovoltaics – applied to both planetary surface power and high power solar electric propulsion
  - Energy Storage – applied to planetary surface power with photovoltaics
  - Nuclear Fission Power – applied to both planetary surface power and nuclear electric propulsion
  - Radioisotope Power – applied to planetary surface power, deep space power, and radioisotope electric propulsion
  - Electric Propulsion – applied to high power solar electric propulsion, nuclear fission electric propulsion, and radioisotope electric propulsion
  - Nuclear Thermal Propulsion
- 2) Each subteam will review previous architecture and roadmapping efforts and map technology requirements against the assumed DRMs and architectures provided by APIO
- 3) Based upon the derived technology requirements, plan out a capability roadmap to meet the requirements
- 4) Assemble the technology roadmaps into broad capability roadmaps (i.e., surface power roadmaps, On-Board Power Roadmaps, Propulsion roadmaps, etc.)
- 5) Iterate roadmaps with SRMs (particularly SRM-13, Utilization of Nuclear Systems for Civilian Space Missions) and other capability roadmaps
- Item 1 will be accomplished during our first meeting (Dec. 1 and 2)
- Items 2 and 3 will be done by the subteams between meetings with telecon tagups
- Item 4 will be done at subsequent team meetings (TBD)
- Item 5 will be accomplished at specified opportunities identified by APIO and as required between roadmap chairs.

# HEP & P Capability Roadmap

## Plans and Schedule

- |   |           |
|---|-----------|
| • Team Formation  | Oct04     |
| • Initiate Weekly Team Telecons                           | Nov04     |
| • Open Workshop to Collect Ext. Input                     | Nov04     |
| • 1 <sup>st</sup> Team Meeting                            | Dec04     |
| • Review with Strategic Planning Council                  | Jan05     |
| • Begin Phase 2 Investment Plan                           | Jan05     |
| • Input to NASA POP Guidance                              | Jan/Feb05 |
| • 2 <sup>nd</sup> Team Meeting                            | Jan/Feb05 |
| • Submit 1 <sup>st</sup> Draft Roadmap for Academy review | Feb/Mar05 |
| • Identify New Initiatives                                | Apr05     |
| • 3 <sup>rd</sup> Team Meeting                            | May05     |
| • Submit 2 <sup>nd</sup> Draft Roadmap for Academy review | Jun05     |
| • Review with Strategic Planning Council                  | July05    |
| • Program Decisions Finalized (Ph. 2 Com)                 | Aug05     |
| • Roadmap Final Product & Phase 1 Complete                | Sep05     |

# HEP & P Status

- Team has been formed
- White papers submitted and made available to all team members
- Interaction with white paper authors today at this workshop
- First team meeting Dec1 and 2 in Washington DC
  - Will discuss and decide on process to proceed
  - Will examine and discuss all relevant previous roadmapping activities and white paper submittals
  - Will discuss and decide on sub-team breakdowns
  - Will decide on assignments and go-forward plan
  - Will discuss how to logistically interact (i.e., telecons, videocons, team meetings, etc.)

# Summary of HEP & P White Paper Topics

- Fuel Cells – 2
- Radioisotope Power Systems – 2
- Electric Propulsion – 5
- Power Conversion – 1
- Nuclear Fission Reactors – 2
- Solar Thermal Propulsion – 1
- Thermal Heat Rejection – 4
- Analysis Tools – 2
- Programmatics – 2
- Power beaming – 3
- Inflatables – 1
- Materials – 4
- Power Management and Distribution – 1
- Solar Electric Propulsion - 1

# HEP & P

## Questions and Answers